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May 15, 1862.

Major-General SABINE, President, in the Chair.

Dr. William Stokes and George Johnstone Stoney, Esq., were admitted into the Society.

The following communications were read:—

I. "On the Sensory, Motory, and Vaso-Motory Symptoms resulting from Refrigeration and Compression of the Ulnar and other Nerves in Man." Second Communication. By Augustus Waller, M.D., F.R.S. Received April 12, 1862.

In the 'Proceedings of the Royal Society,' No. 46, I have given a brief account of the effects of refrigeration of the ulnar nerve in man, by the application of ice. After repeated experiments on this nerve on myself, I never had occasion to witness any permanent disturbance in the nerve from the application of the ice, beyond a slight hyperæsthesia, which may have been partly due to the increased attention of the mind directed to the part whose functions were under investigation.

The like immunity does not extend to experiments in which a much greater degree of cold is employed, as will be seen from the following instance:—

September 13, 1861.—A freezing mixture, consisting of equal parts of pounded ice and common salt, was applied to the elbow of the left arm over the ulnar nerve. The subject of the observation was a gentleman in perfectly sound health, aged twenty-seven.

Before the application of the mixture, the temperature between the little and ring fingers and the index and median was the same. Successive observations gave the following results:—

Duration of application of refrigerating mixture. Minutes.	Temperature Cent. between ring and little fingers at roots.	Temperature Cent. between index and median fingers at roots.
5	25°·3	27°·8
7	25·6	28·0
10	26·1	28·2
25	26·6	29·6

Duration of application of refrigerating mixture.	Temperature Cent. between ring and little fingers at roots.	Temperature Cent. between index and median fingers at roots.
Minutes.	°	°
27	27·8	30·1
29	26·6	29·1
33	26·4	28·5
35	27·5	29·0
37	29·2	28·8
40	30·5	28·0
44	31·2	27·5
46	32·5	27·0
47·5	33·5	26·6
50	33·5	26·0
52	33·8	26·0

At this time the freezing mixture was removed.

In the course of the application the following results were observed:—

Soon after the application of the freezing mixture, the nerve began to be painful from the elbow downwards; after twenty-seven minutes' application the little finger was already somewhat paralysed and insensible. When the nerve was compressed or vibrated, it was found to be very sensitive and tender, and its excitability much increased*.

After thirty-two minutes the symptoms were—

1st. Paralysis of the movements of the little finger almost complete.

2nd. A state of semi-flexion of all the fingers, diminishing from the little one outwards, so that they could not be straightened completely by the extensor muscles.

3rd. Great weakness in all the fingers and thumb, so that great difficulty was experienced in grasping or holding any object.

4th. Complete loss of the power of abduction and adduction of the fingers, so that when they were extended as far as possible they

* I apply the term "vibration of a nerve" to the act of pushing it aside with the tips of the fingers so as to render it tense, and then suddenly removing them. By so doing a sound is generally produced by the nerve, as by a vibrating cord. This little operation causes a slight degree of pain, sufficient to enable us to judge of the degree of sensibility of the nerve. It likewise causes slight movements of the last finger from muscular contraction, sufficient to indicate the degree of excitability of the nerve. For further account see my paper on the subject of irritation of the ulnar nerve, &c. in the 'Medical Gazette.'

remained spread out without there being any power of bringing them together.

After fifty-two minutes the freezing mixture was withdrawn, and the skin at the elbow, which was completely frozen, was allowed to thaw. During this process the arm and hand became rapidly very painful upwards and downwards in the course of the nerve, the pain even extending to the chest, where there was a feeling of great uneasiness and constriction. At the same time the heart's action was so much lowered as to threaten immediate syncope, which was, however, prevented by a free administration of ammonia and spirits. An hour after the removal of the freezing mixture the temperature (Cent.) was as follows:—

Left hand, between the index and median	20°·5
„ between the little and ring fingers....	21·2
Right hand, between the index and median	21·8
„ between the little and ring fingers ..	21·8

September 16th.—Over the skin which had been frozen there was vesication and inflammation of the subcutaneous tissue, which was swollen around the part blistered to the extent of 2 or 3 inches over the arm and forearm. Over the prominent parts of the elbow-joint the bones were very tender on pressure. The ulnar nerve was likewise exceedingly painful to the touch up the arm and down the forearm and the hand. The brachial plexus was very tender at some points. Over the little finger and the inner side of the ring finger the skin was nearly insensible. Friction over these parts caused a sensation of heat, pricking, and discomfort. The temperature of these parts was not more elevated than other parts of the hand. The paralysis of the muscles of the hand was in the same condition as on the 14th. The two points of compasses, when more than an inch apart, were felt as one over the palmar surface of the little finger.

September 17th.—Paralysis and anæsthesia the same as the day before. The hyperæsthesia of the ulnar nerve was diminished.

September 22nd, one week after application of ice.—Considerable and constant hyperæsthesia is experienced in the little finger and down the ulnar side of the hand. The power of motion is somewhat restored, but neither the little nor any of the other fingers can

be completely extended. The spot to which the freezing mixture was applied is still sore, and the ulnar nerve immediately under it very sensitive.

The following observations were made on the temperature of both upper extremities :—

Right (unaffected) side.	Left (paralysed) side.
28°·6 Cent. (radial side of second finger).....	26°·6.. diff.—2°
24·7 (after some minutes' exposure to *cold air*)	22·7.. diff.—2°
34·3 (at bend of arm)	33·7.. diff.—·6
33·4 (at middle of inner side of arm)	33·6.. diff.+·2

Right forearm.		Left forearm.	
Radial side.	Ulnar side.	Radial side.	Ulnar side.
31°·4	29°·1.. diff. 2°·3.	31°	28°·6.. diff. 2°·4

After some minutes' exposure to cold air, the temperature of the little fingers of both hands sunk to—

	Right side.	Left side.
(1)	22°·1	20°·7.. diff. 1°·4
(2)	21·4	19·7.. diff. 1·7
(3)	21·5	19·7.. diff. 1·8

Both arms were then well exercised; as the result of which the temperature rose in successive observations to—

	Right side.	Left side.
(1)	31°	25° .. diff. 6°
(2)	34	31·1.. diff. 2·9
(3)	34·5	31·5.. diff. 3
(4)	35	33·5.. diff. 1·5
	35	34 .. diff. 1

These observations show :—

(1) That the mean difference of temperature between the paralysed and sound arms was 2° Cent.=3°·6 Fahr.

(2) That this difference lessened as the temperature of both arms was lowered.

(3) That the temperature of the sound side was *at first* increased much more rapidly than that of the side paralysed, but that after a short time the normal difference 2° was re-established.

September 27th.—The power of motion in the little finger is

almost restored; but there is still sensible hyperæsthesia in it, as well as on the inner side of the palm of the hand. There is also some stiffness in that finger, and a complete inability, when the fingers are extended, to bring them into opposition with one another.

The spot on the upper arm to which cold was applied is now quite healed, and all swelling has subsided; but the ulnar nerve is still very sensitive on being touched.

The weakness of the left hand in grasping objects, as in using a fork at dinner, &c., even ten days after the experiment, was most perceptible.

The temperature on the radial side of the little finger of both hands is—

Right.		Left.
33°·5 Cent.	.....	32°·3..diff. 1°·2

October 1st.—Temperature of hands.

Right.		Left.	
Little finger.	Fore-finger.	Little finger.	Fore-finger.
33°·5	33°·7	32°·2	32°·5

There was still considerable numbness in the little finger and on the inner side of the palm of the hand. The fingers could now be extended almost as completely as those of the right hand, but they could not be easily expanded, or brought into opposition with one another. At times the nerve was very painful along its whole course, from the elbow downwards. This is mostly the case after the arm has been used a little. Pain at these times, even if not actually present, was easily induced by placing the arm in a dependent position so as to cause congestion of its vessels, and it was immediately relieved by elevating the limb above the head so as to deplete the vessels. The nerve was very sensitive to pressure all along its course, from the elbow downwards, although all painfulness arising from the inflammation produced in the cutaneous tissue by the cold had disappeared for some days.

On both hands being held for some minutes in a stream of running water at a temperature of 14°·4 Cent., considerable pain was experienced in the little finger and inner side of the left hand; and on withdrawing both hands their temperature was—

Right little finger.	Left little finger.
16°·5	16°·3

The effect of the reduction of temperature on the paralysed hand was very distinct; the three inner fingers were more or less contracted, the little one being semiflexed, and could not be extended completely, those of the right hand being easily extensible.

In half an hour the temperature of both hands had risen to—

Right little finger.	Left little finger.
°	°
34·2	33
34·5 (12 P.M., one hour after immersion).....	34

At this moment, although the temperature of the paralysed fingers was higher than before immersion in water, the little finger was still semiflexed, and none of the others could be perfectly extended.

February 14th, 1862.	Right hand. Cent.	Left hand. Cent.
	°	°
Temperature between little and annular fingers	19·5	18·5
,, ,, annular and median	18·8	18·3
,, ,, median and index	19·0	18·1
,, ,, thumb and index	21·1	20·1
,, of palmar surface of little finger at root	18·0	17·9
Temperature of forearm, posterior surface, lower fourth	28·3	28·0
Temperature of radial side of forearm.....	27·0	27·6
,, of palm of hand when closed....	19·8	19·6

There is still a feeling of stiffness in the little finger, accompanied with slight inability to move it. There is also considerable sensitiveness along the course of the ulnar nerve in the palm of the hand when compressed or percussed. The fingers can be moved to and from one another more freely, but the power of so doing is still imperfect; and that of grasping, so far as the whole hand is concerned, is much weaker than in the other hand. Cutaneous sensibility is decidedly inferior over the dorsal and palmar surface of the inner part of the hand and two corresponding fingers when compared with the right, but the sensibility to cold is the reverse; whenever the left hand becomes cooled by exposure, the little finger is always more or less painful. Vibration of the nerve at the elbow produces the same effect on both sides.

For about two weeks during the cold weather in this month there existed over the palmar surface of the left little finger a chilblain, the only one to be found on either hand.

The left hypothenar eminence was likewise then discovered for the first time to be less firm and smaller than on the right hand, as if atrophied in consequence of the results of the experiment; and to such a degree that the swelling formed by this eminence on the inner side of the hand, which was considerable on the right hand, was nearly absent on the left.

To ascertain how far this difference is normal in right-handed persons, I examined the hands of several persons accustomed to manual labour, where the preponderance of the upper right limb is great; but I found much less than in the present instance. I must therefore attribute this atrophy of the left hypothenar eminence partly to the semi-paralysis of the muscles, and especially to the diminished nutrition from constriction of the vessels.

Compression of the Ulnar Nerve.

I compress this nerve simply by resting the elbow on some hard body slightly padded, and holding a heavy book in the hand to increase the weight on the elbow, which would otherwise be insufficient.

The symptoms are sensory, motory, and vaso-motory.

The sensory symptoms are those first perceived, being the well-known formication over the palmar territory of the nerve, viz. the little finger, the inner side of the annular, and the hypothenar eminence.

The symptoms of anæsthesia over the dorsal surface of the hand and fingers do not appear until a later period, when the anæsthesia is considerably advanced in the palmar portion.

While the anæsthesia is gradually progressing, the muscles of the hand governed by the ulnar nerve become weakened, stiff, and imperfect in their movements.

The first muscles which lose their power are the interosseous, which govern the adductive and abductive movements of the fingers. On trying alternately to spread out and to bring the fingers in contact, we find them to move imperfectly and weakly, in a trembling uncertain way, like the movements of old age. Later still the little

finger cannot be placed in apposition with the annular, but remains apart at an angle of 10 or 15 degrees. At the same time paralysis of the abductor and adductor muscles of the other fingers takes place.

The index and thumb alone retain some of their powers of adduction and abduction; the former probably from the action of its proper extensor; the latter from its abduction not being animated by the ulnar nerve.

When paralysis of these muscles is complete, the appearance of the hand, when the fingers are in extension, is pathognomic, and as follows:—

The little finger in complete adduction at about an angle of 40° from the annular, which is likewise a little apart from the median. Both these fingers are slightly flexed and incapable of *complete extension*. The flexor muscles are much weakened, as might be anticipated from the distribution of the ulnar nerve. In addition, the flexion movements of the thumb and the extensor power of this and all the fingers are considerably weakened.

The tendency of the fingers to semiflexion, and the inability of the little, the annular, and even to a slight extent the median finger to accomplish complete extension is probably referable to the state of tonicity of the paralysed flexors. The weakness of the extensor and flexor powers of the thumb are not, in my opinion, sufficiently accounted for by the lost power of its adductor muscle. Still less can we account for the diminished power of extension of the other fingers by any direct or descending action of the ulnar nerve. I am led therefore to refer the diminished power, in this case, of the extensor muscles of the fingers to reflex action of the ulnar nerve. In support of this view, I may state that I have not unfrequently experienced, after vibrating the ulnar nerve at the elbow, a great lassitude of the whole limb, particularly marked over the deltoid muscle, to so great an extent as to occasion much discomfort for at least an hour afterwards.

Vaso-motory symptoms.—Under this head I include all the perturbations of temperature of the integuments animated by the ulnar nerve, which attend its compression.

Mechanical irritation of this nerve, such as vibrating it, will frequently cause an immediate fall of 0°·5 Cent. to 1°·0 Cent. of the

mercury in a thermometer placed between the little and annular fingers, while the others remain nearly unaffected.

It is still more easy to ascertain this influence when the nerve is paralysed by pressure.

Thus, in the following observation, I found—

	Cent.
When the integuments of the little finger began to tingle between the roots of the little and annular fingers	=22·4
At the same time between the roots of index and median	23·4
When the anæsthesia over the little finger was more advanced and its adductor muscle somewhat paralysed between roots of little and annular fingers	21·4
At the same time between index and median	22·4
Some minutes later between little and annular finger	21·0
At the same time between index and median	22·3
When the paralysis and anæsthesia were nearly complete between little and annular fingers	19·0
At the same time between index and median	22·3
The temperature of the right hand between the fingers remained nearly stationary	24·0

In other experiments on compression of the ulnar nerve I have observed a much greater fall of temperature as the integuments became insensible.

With regard to the elevation of temperature, I have never been able to obtain it by compression of the ulnar nerve to the extent produced by refrigeration.

Compression of the Left Radial Nerve.

Feb. 10, 1862.—This nerve was compressed at the lower part of its course at the arm, where it winds round the humerus to its external side. This was effected simply by pressing the outer part of the arm against the padded arm of a chair.

In about half an hour the skin of the back of the hand had become somewhat insensible, and the muscles of the forearm so much weakened that the hand dropped by its own weight. These symptoms continued to increase until the extensor muscles of the forearm were quite paralysed. Examination three-quarters of an hour after the commencement of the experiment gave as follows:—

The skin over the back of the forearm, that of the carpus, of the thumb, of the two first phalanges of the index, and over the outer half of the thenar eminence was nearly insensible to the contact of external bodies; but when pricked or pinched, pain was produced of a hot, burning character, which lasted for about a minute after the removal of the cause. Over the back of the other fingers, *i. e.* the median, annular and little fingers, and the last phalanx of the index, no loss of sensibility could be detected.

Flexion of the fingers was very imperfect; their tips with difficulty could be made to touch the palm of the hand. The movements of the last phalanx of the thumb were almost paralysed, while those of its second phalanx and metacarpal bone appeared little affected.

The apposition of the tips of the thumb and index, as well as that of the thumb and median, could be made, but not that of the thumb and tips of the two last fingers. All extension of the carpus on the forearm was impossible. The hand, when left to itself, fell into a state of semiflexion of the carpus on the forearm, with semiflexion of the fingers; while the thumb placed itself on the palm of the hand by the flexion of its metacarpal bone and first phalanx, the second phalanx remaining unbent.

The movements of supination of the forearm and abduction of the carpus were almost entirely paralysed.

	Left side. ° Cent.	Right side. ° Cent.
Temperature between roots of thumb and index.	28·0	28·3
Temperature over dorsum of first phalanx of index	23·4	26·7
Temperature over dorsum of second phalanx of index	20·2	25·7
Temperature over dorsum of first phalanx of little finger	19·0	27·0

One minute after removal of the pressure the thumb could be flexed at both phalanges into the palm of the hand; apposition of the thumb and annular finger was possible. The skin over the part supplied by the nerve was rather less numb.

Two minutes later the carpus could be placed in a straight line with the forearm, but could not be retained in that position.

Thirteen minutes later the hand was in the same condition. All delicate movements, such as buttoning and unbuttoning the dress, were impossible, although the sensibility at the tips of the index and thumb was equally acute in both hands.

A quarter of an hour later the temperature of the hand was as follows:—

	Left hand. ° Cent.	Right hand. ° Cent.
Temperature over dorsum of carpus	23·0	25·0
,, between roots of index and median	19·5	21·9
,, between roots of annular and little finger	19·8	21·6
(1) Temperature over dorsum of forearm	29·0	32·1
(2) ,, of external side of forearm	29·0	31·2
(3) ,, of external side of forearm	27·5	29·0

Temperature of (1) and (2) was obtained with the forearm covered by the usual dress; that of (3) was obtained after the arms had been denuded for some time.

February 10, 2.25 P.M.:—

	Left side. ° Cent.	Right side. ° Cent.
Temperature between the roots of the thumb and index	18·8	23·5
Temperature over dorsum of median and metacarpal bone	19·0	23·5
Temperature between the tips of thumb and index	19·0	30·5
,, between roots of index and median	26·5	29·5
,, between median and annular	30·3	30·9
,, between annular and little finger	31·3	30·5
,, (second observation) between thumb and index	21·0	32·3
Temperature over dorsum of forearm, under coat and flannel vest	26·0	29·3
Temperature of anterior part of forearm, covered as above	28·0	30·5

6.45 P.M. After an hour's walk:—

Temperature between thumb and index	23·3	32·5
,, between index and median at roots	30·8	31·5
,, between median and index	33·7	33·3
,, between annular and little finger	34·3	34·5

	Left side. ° Cent.	Right side. ° Cent.
Temperature over dorsum of carpus over second metacarpal bone	26·8	29·3
Temperature over dorsum of first metacarpal bone	28·5	31·1
Temperature over dorsum of first phalanx of thumb	30·8	30·2
Temperature of anterior part of first phalanx of thumb	32·1	32·2
Temperature over thenar eminence	28·5	32·5
Temperature over dorsum of forearm (lower part covered)	29·0	31·5
Temperature over dorsum of forearm (upper part covered)	28·8	30·6
Temperature over anterior part of forearm (lower extremity covered)	30·3	32·6
Temperature over anterior part of forearm (upper extremity covered)	30·5	31·5

The sensibility of the skin was in the same condition as on the previous day; the hand continued to drop, the fingers remaining in a state of semi-flexion as before, and there existed the same difficulty in performing all delicate movements. In conveying food to the mouth the supinators act so imperfectly that the operation is performed with considerable difficulty.

February 11, 10 A.M.:—	Left side. ° Cent.	Right side. ° Cent.
Temperature over dorsum of thumb	19·0	21·9
,, between roots of thumb and index	21·7	27·0
,, between roots of index and median	21·5	23·1
,, between roots of median and annular	21·5	24·0
,, between roots of annular and little finger	21·0	22·8
Temperature of palm of hand when closed	22·6	24·8
Temperature over dorsum of forearm, lower extremity (uncovered)	25·1	30·5
Temperature over dorsum of forearm, middle part (covered)	28·7	30·8
Temperature over anterior surface of forearm, lower extremity (uncovered)	28·5	31·0
Temperature over anterior surface of forearm, upper part (covered)	30·2	31·0

Over the dorsum of the thumb, carpus, and forearm the sensibility was slightly improved.

Buttoning could be performed with difficulty. The fingers, the carpus, and the forearm could now be placed in a straight line. Abduction of the thumb, which on the right side forms an angle of 90°, on the left can be made to an angle of 45°.

February 12, 8 A.M. :—	Left side. ° Cent.	Right side. ° Cent.
Temperature between thumb and index at roots.	31·9	32·7
,, between index and median	31·7	32·3
,, between median and annular	31·8	32·4
,, between annular and little finger..	31·1	32·0
,, of palm of the hand when closed..	30·2	34·0
,, over lower part of forearm	30·0	31·3

The hand felt stronger and the movements were more free. Buttoning was effected more easily. Extension of the left hand backward as free as that of the right while the fingers were semiflexed, but not when they were extended.

February 13 :—	Left side. ° Cent.	Right side. ° Cent.
Temperature between thumb and index at roots.	24·3	27·8
,, between index and median	23·5	24·3
,, between median and annular	26·0	25·0
,, between annular and little finger..	26·7	26·8
,, over dorsum of thumb	27·5	30·0
,, over dorsum of index	25·3	25·9
,, over dorsum of lower part of forearm	26·5	28·3
,, over dorsum of upper part of forearm	31·0	31·8

Left hand felt much stronger. Left thumb could be placed in abduction at an angle of 60° with the index.

On the following days the sensibility of the skin continued gradually to improve, and also the motor powers, and after the lapse of twelve days from the date of the experiment there existed no difference in the sensibility, motor power, and the temperature of the two hands.

Compression of the Right Median Nerve.

January 2, 11 A.M.—The arm was allowed to hang over the back of a chair so as to compress the median nerve and brachial

vessels about 2 inches above the bend of the arm. In the course of about half an hour the nerve became paralysed, and the following symptoms were observed.

Motory Symptoms.—The thumb was incapable of flexion at the last joint, but could be flexed on the metacarpal bone, so as to be brought in contact with the tips of the three first fingers, but not with that of the little finger. There was considerable stiffness of the thenar muscles, particularly of the abductors. The index and median fingers remained slightly flexed, but by an effort of the will they could be straightened and could perform all movements of adduction and abduction. The index could only be made to flex very slightly, but the median could be completely flexed. The annular and little fingers retained all their movements, but felt weak. Flexion of the entire hand on the forearm was imperfect, and the muscles of the external part of the forearm felt very stiff.

Sensory Symptoms.—The thumb and two first fingers felt cold and numb, and nearly insensible, but when pressed, a sensation of heat was experienced. The insensibility at the tips of the thumb and two first fingers was nearly complete when objects were brought in contact with them. Numbness of the skin existed at the anterior part of the forearm.

	Right hand. ° Cent.	Left hand. ° Cent.
Temperature between index and thumb	20·4	
Temperature between index and median at roots of fingers	26·5	34·3
Temperature between median and annular	25·3	34·8

Some minutes after pressure was removed and motor power had returned, while there still remained some numbness and insensibility of the fingers, the

	Right hand. ° Cent.	Left hand. Cent.
Temperature was between index and median fingers	27·2	
„ between median and annular	25·3	
A quarter of an hour later:—		
Temperature between index and median fingers.	28·0	34·3
„ between median and annular	26·8	34·5
Twelve o'clock:—		
Temperature between index and median	27·6	
„ between median and annular	27·2	

There was still slight numbness of the fingers. After the right arm and hand were exercised for a few minutes, the

	Right hand. ° Cent.	Left hand. ° Cent.
Temperature between index and median	27·8	
,, between median and annular	26·8	
At 2 P.M., after walking and using both hands:—		
Temperature between index and median	29·8	23·0
,, between the tips of thumb, index, and median	31·2	22·7

At 7 P.M. the temperature of both hands was the same.

II. "On the Rigidity of the Earth." By Professor WILLIAM THOMSON, F.R.S. Received April 14, 1862.

(Abstract.)

The author proves that unless the solid substance of the earth be on the whole of extremely rigid material, more rigid for instance than steel, it must yield under the tide-generating influence of sun and moon to such an extent as to very sensibly diminish the actual phenomena of the tides, and of precession and nutation. Results of a mathematical theory of the deformation of elastic spheroids, to be communicated to the Royal Society on an early occasion, are used to illustrate this subject. For instance, it is shown that a homogeneous incompressible elastic spheroid of the same mass and volume as the earth, would, if of the same rigidity as glass, yield about $\frac{7}{9}$, or if of the same rigidity as steel, about $\frac{2}{5}$ of the extent that a perfectly fluid globe of the same density would yield to the lunar and solar tide-generating influence. The actual phenomena of tides (that is, the relative motions of a comparatively light liquid flowing over the outer surface of the solid substance of the earth), and the amounts of precession and nutation, would in the one case be only $\frac{2}{9}$, and in the other $\frac{3}{5}$ of the amounts which a perfectly rigid spheroid of the same dimensions, the same figure, the same homogeneous density, would exhibit in the same circumstances. The close agreement with the results of observation presented by the theory of precession and nutation, always hitherto worked out on the suppo-